
Water-Quality Issues Related to Uranium In Situ Recovery Sites

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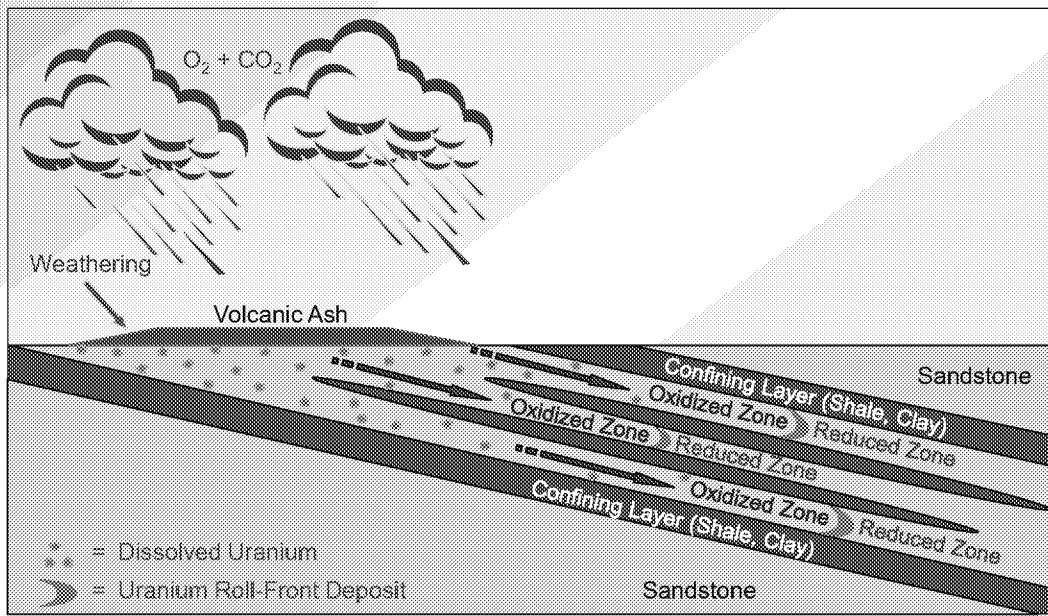
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Uranium Roll Front: Formation

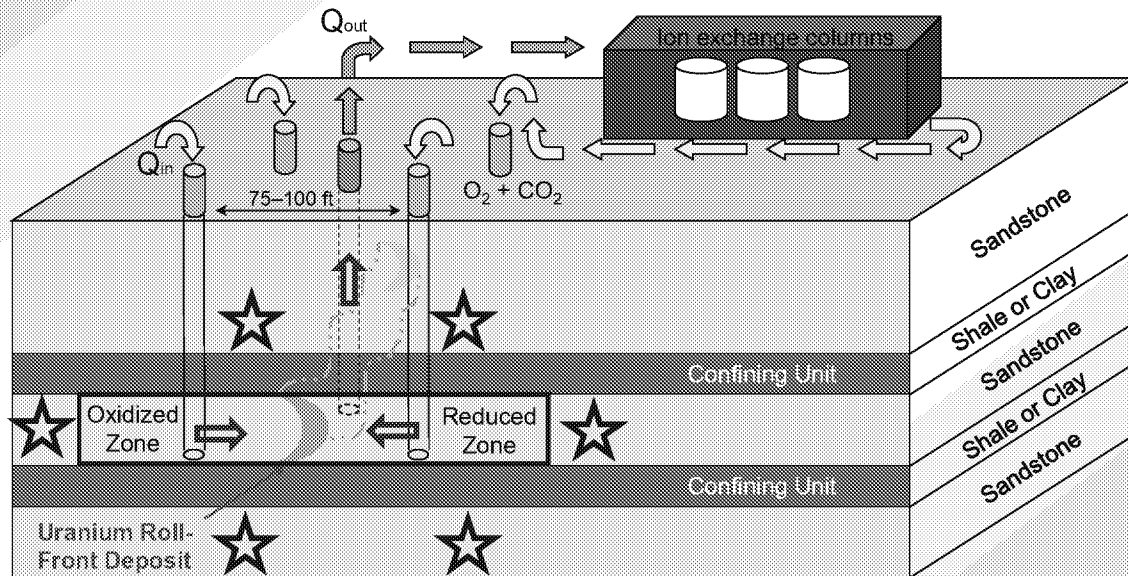


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Oxygen and carbon dioxide are key components in mobilizing uranium from source material, including volcanic ash. Uranium precipitates at redox boundaries, which moves down-dip or downgradient at centimeters or less per century, depending on groundwater flow velocities, oxygen content, and carbon content at the redox boundary. This redox boundary becomes an enriched uranium deposit over geologic time.

In Situ Recovery (ISR) Process



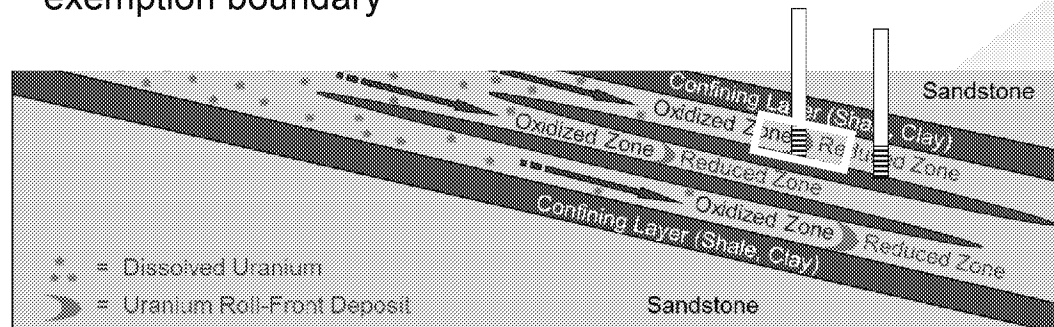
The addition of oxygen and carbon dioxide reverses the depositional processes and keeps uranium in solution. Uranium is pumped from a central well to ion exchange columns at the surface, where uranium is removed, and the water is re-injected.

The blue box is an aquifer exemption boundary that is issued by the U.S. Environmental Protection Agency to allow the ISR process to proceed in this localized area.

The stars are nearby monitoring locations.

Groundwater Quality Issues

- Aquifer outside of the ISR zone could be used for:
 - Agricultural irrigation
 - Livestock water
 - Drinking water
- U.S. Environmental Protection Agency (EPA) requirement:
No change in groundwater quality outside of the aquifer exemption boundary



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White box indicates aquifer exemption boundary with ISR wells within that boundary.

Aquifer exemption boundary recognizes the presence of the uranium ore body, and that the groundwater within that ore body is not suitable for drinking water (often high uranium and/or radium concentrations).

The well outside of the white box is a downgradient user of the groundwater.

Determining the ISR influence on groundwater outside of the aquifer exemption boundary is the focus of this talk.

Groundwater Quality Issues: Reality

- Restoration to full, pre-ISR water quality is difficult because:
 - The ISR process has significantly altered the solid phase
 - Aquifer heterogeneities limit restoration efficiency
- Past ISR closures
 - Some went to “class-of-use”
 - Sometimes 1 year or less of monitoring
- Proposed EPA regulations
 - 3 years of monitoring in conjunction with geochemical modeling
 - 30 years of monitoring



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Reductants are often used in the restoration process

Not going to get into all the restoration techniques

One year of monitoring is probably not sufficient

New proposed regulations might require up to 30 years of monitoring

“Class-of-use” argument is not recognized by the Nuclear Regulatory Commission (NRC)

With typical groundwater flow rates, any downgradient impacts will be decades in the making

Stakeholder Interest and EPA regulations

- Determine “no impact on downgradient water quality” before ISR development or closure
 - Future rock-water interaction
- Focus on downgradient water quality
 - Appropriate data collection (rock and water)
 - Applicable laboratory and field testing
 - Predictive reactive transport modeling
- Pre-ISR data
 - General site knowledge
 - Core collection
 - Batch testing
 - Column testing
 - Reactive transport modeling



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Before an ISR facility is closed, it is not easy to determine whether or not the downgradient water quality will be impacted given slow groundwater flow rates, thus need to know the downgradient rock-water interaction and points in the second main bullet. Mention DOE as a stakeholder, with remediated uranium mill sites that are near and/or downgradient from current and/or proposed uranium ISR sites. ISR facilities do not transfer to DOE. Mention that once an ISR facility is “closed” through Nuclear Regulatory Commission approval, groundwater can again be used for purposes that are consistent with the state’s class-of-use designation.

Empirical Data and Parameters for Modeling

- Contaminant sorption/desorption
 - With changes in geochemistry along the groundwater-flow path due to rock-water interaction
- Contaminant precipitation/dissolution
 - With changes in geochemistry along the groundwater-flow path due to rock-water interaction
- Dual porosity mechanisms (long tailing affect)
 - Geologic layering
 - Fractured rock, or
 - Large grain size distributions



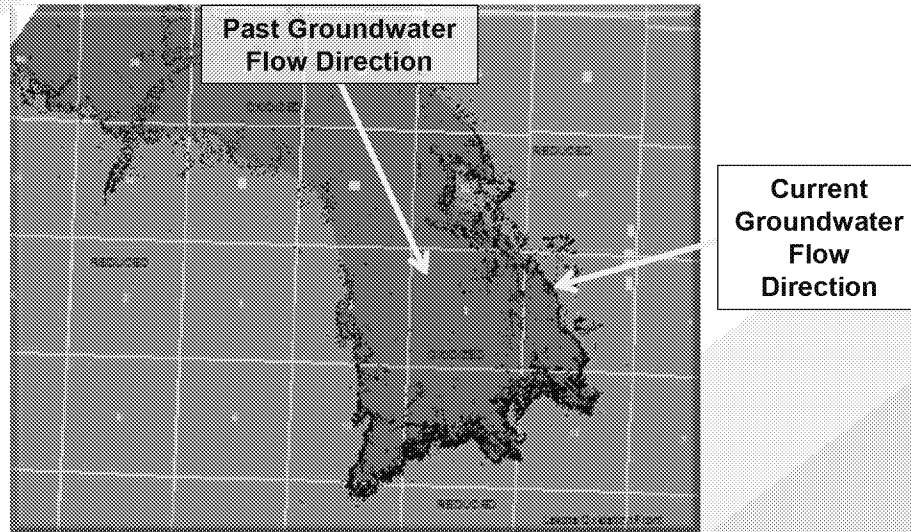
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Key items of interest before getting into testing details

General Hydrogeology

- Geology (rock)
- Groundwater flow directions and velocity (water)



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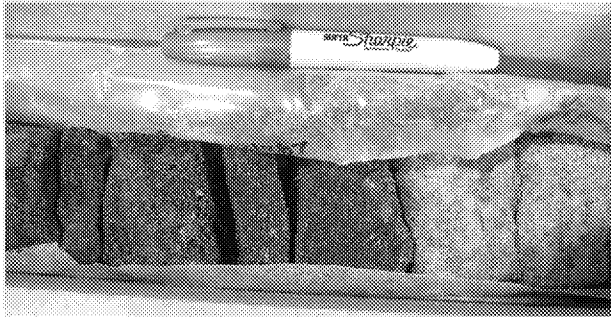
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General hydrogeology is part of the initial permitting process, but complexities need to be fully understood.

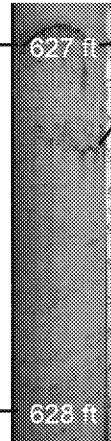
Example: Dewey Burdock site in southwestern South Dakota, where the groundwater flow direction has changed a full 90 degrees through geologic time.

This situation creates an area where oxidized solid phase material occurs downgradient from the ore zone. Note that the ore occurs along the boundary of the oxidized (red) and reduced (grey) zones.

Collect Core

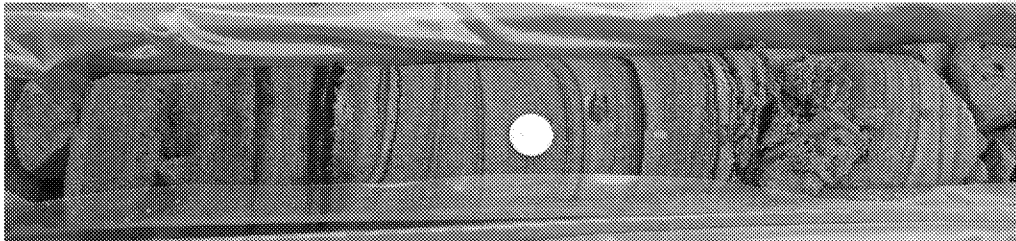
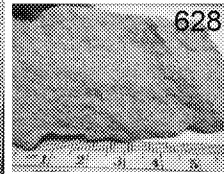


Characterize the mineralogy



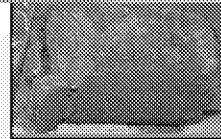
Organic bands with minor deformation

Core is mostly well-sorted, massive, medium-grained gray sandstone with localized organic zone



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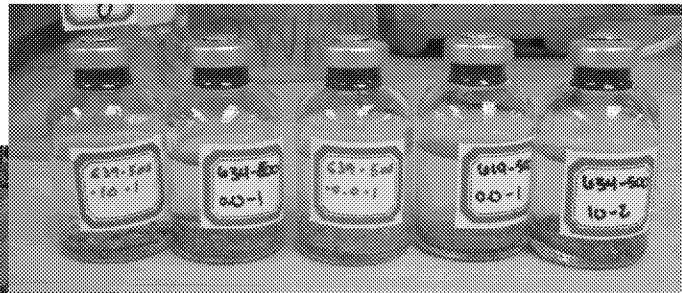
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Some examples of oxidized core, ore zone, and reduced zone core.
Cannot begin to do any future predictions without knowing the solid-phase mineralogy.

Batch Testing

Vary geochemistry to get sorption and precipitation potential



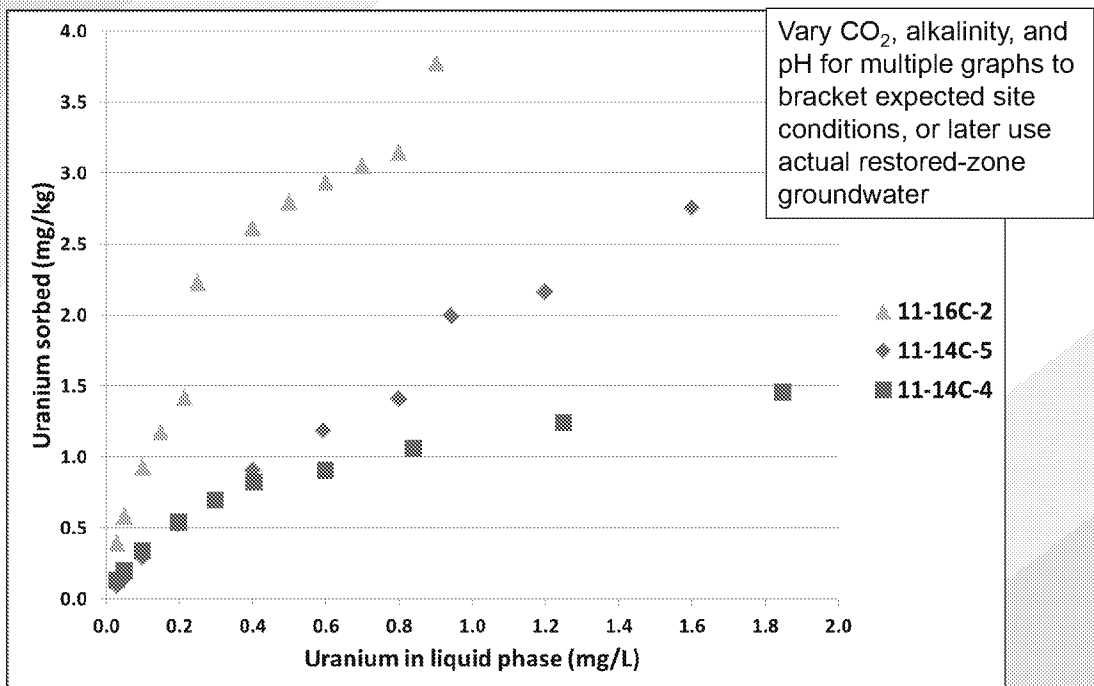
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Each vial is a batch test of rock-water interaction for uranium sorption and/or precipitation. Generally, vary the uranium concentration, alkalinity, and pH to test the influence on uranium sorption.

Example Batch Test Results



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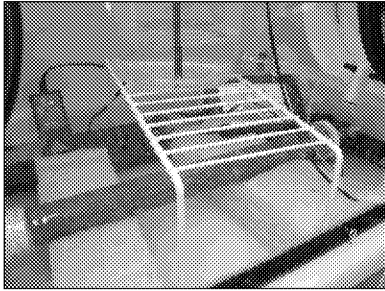
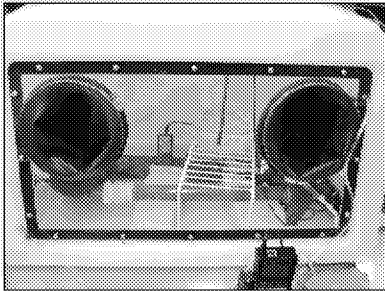
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Explain that these results show equilibrium sorption; thus, given an added amount of uranium, the graph shows the measured amount of uranium sorbed to the three different solid-phase samples.

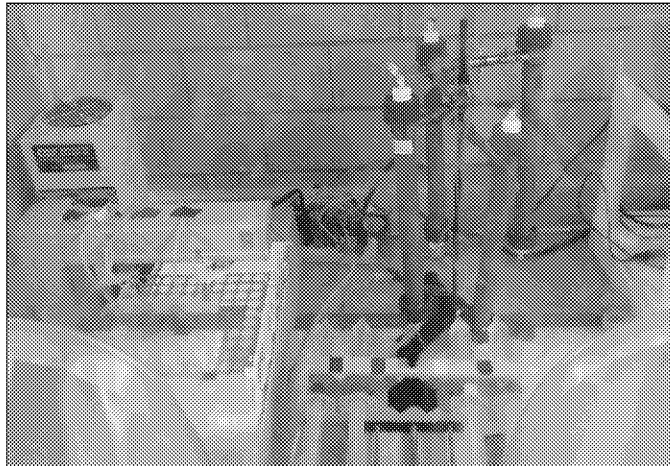
Precipitation could also be important, thus the importance of maintaining reducing conditions (sealed vials in previous slides and glove boxes for column work).

Time scale for reducing conditions to occur appear to be important. Batch tests are relatively short time frames that may not allow for uranium precipitation to occur under reducing conditions.

Column Testing



Column in a glove box at Los Alamos National Lab



Columns in a glove box at the South Dakota School of Mines and Technology

Also, vary CO₂, alkalinity, and pH to bracket expected site conditions, or later use actual restored-zone groundwater

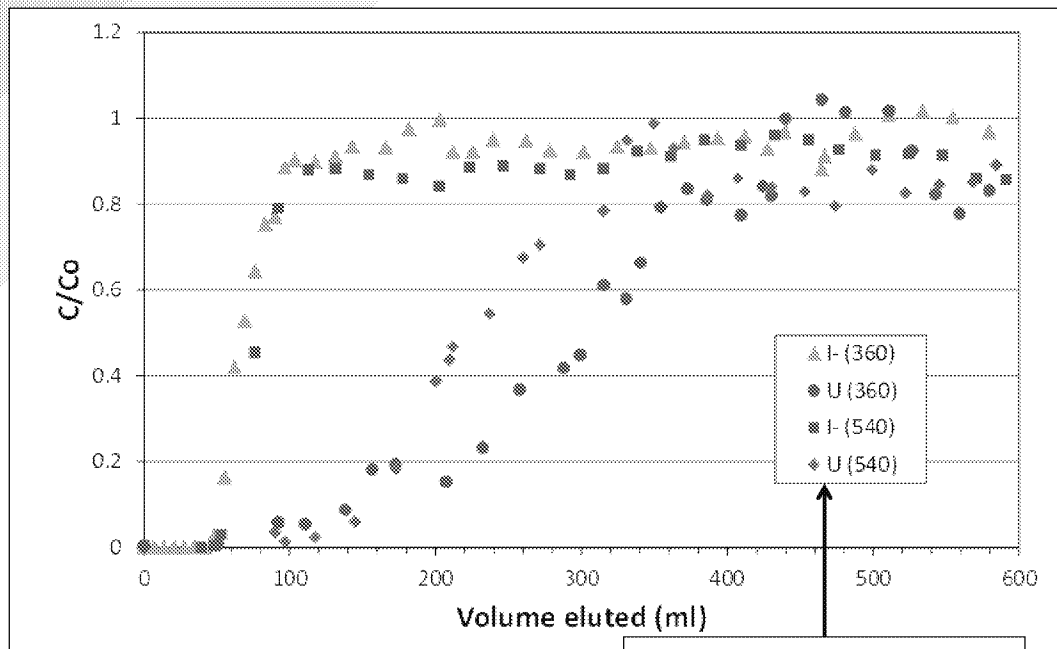


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Pictures show column testing being done in anaerobic glove boxes to maintain reducing conditions. Thus, allowing for uranium precipitation, if it has the potential to occur. Again, the short lab time frame could be an issue.

Column Testing Example Results



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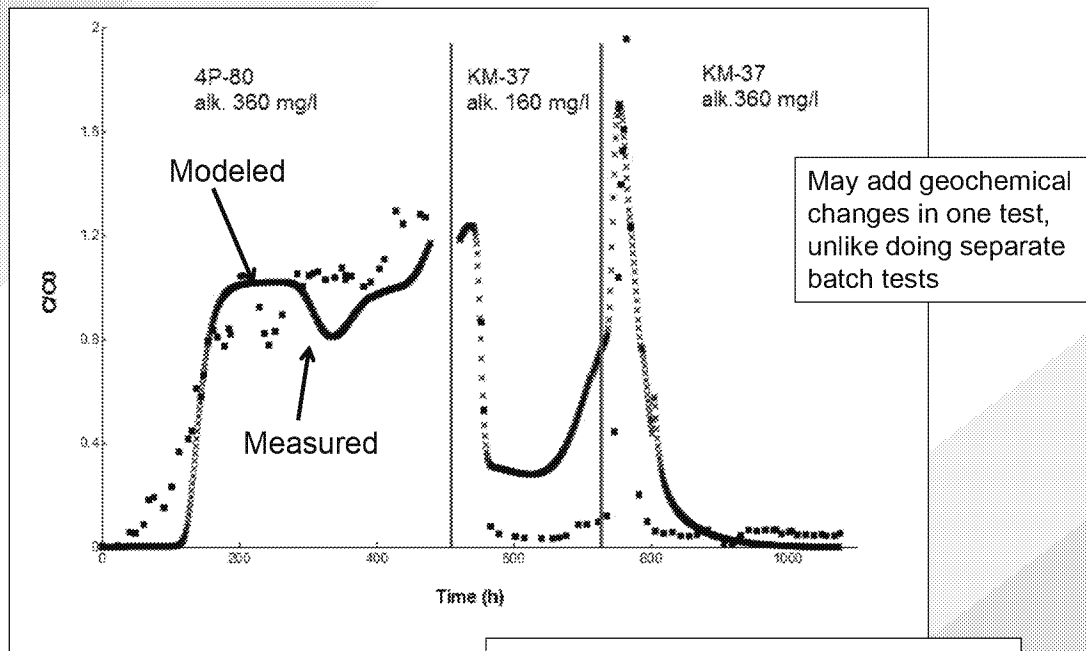
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I- = iodide (conservative)
U = uranium (sorptive)
Different alkalinities in mg/L

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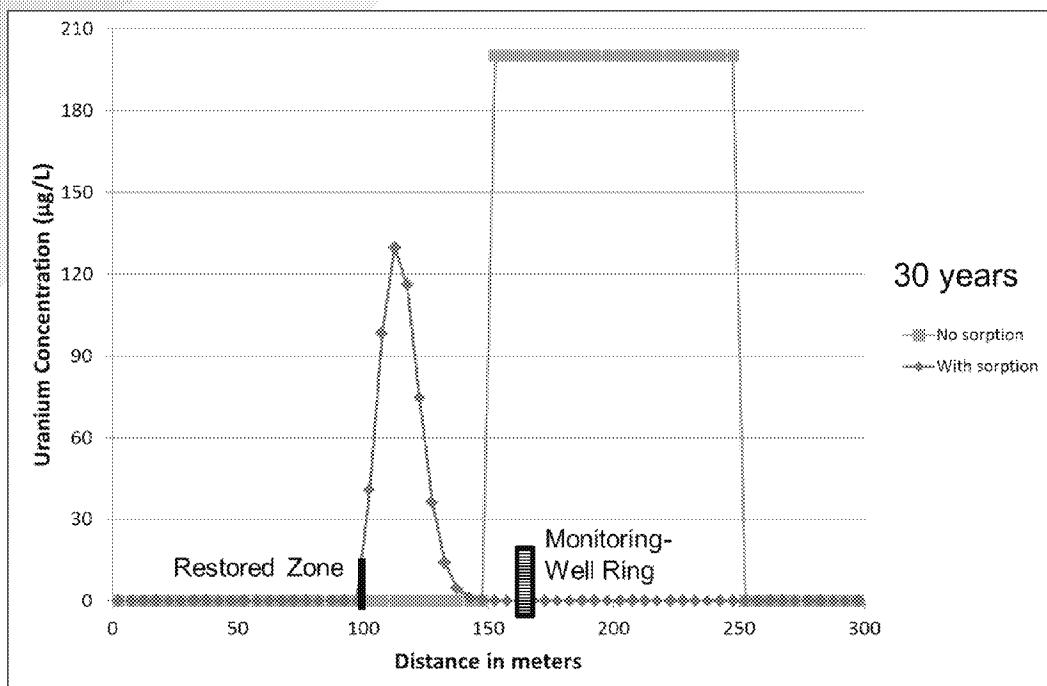
Iodide shows conservative behavior and uranium shows sorption to the solid phase.
The sorption, and thus natural attenuation, is increased when the alkalinity is lowered.

Column Testing Example Results (continued)



4P-80 is unrestored ISR groundwater and KM-37 is background groundwater.

Reactive Transport Modeling



Data from batch and column tests can be used as input parameters for reactive transport modeling that accounts for geochemical changes and rock-water interaction.

Example shows a prediction at 30 years, showing strong natural attenuation of uranium.

This example shows that the monitoring well ring location is okay for conservative elements, but too far out for adequate detection of uranium over the next 30 years. Closer monitoring wells may be needed for earlier detection.

Post-Restoration Data

- Post-restoration core
- Revisit batch testing
- Revisit column testing
- Field testing
- Revisit reactive transport modeling
- Long-term monitoring data



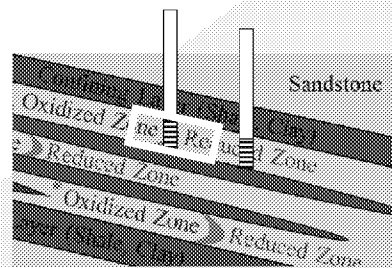
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Long-term monitoring data is good to have, but does not help with shorter-term need for a decision on closure.

Post-Restoration Additional Testing: Restored and Downgradient Zones

- Test restored-zone core with background groundwater to produce an evolved background groundwater (long-term groundwater from the restored zone)
- Conduct batch and column tests on the downgradient core with:
 - Unrestored groundwater (worst case)
 - Final restored groundwater (real case)
 - Evolved background groundwater (future case)
 - Background groundwater (best case)



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First point gets at the very long-term geochemical stability of the restored zone

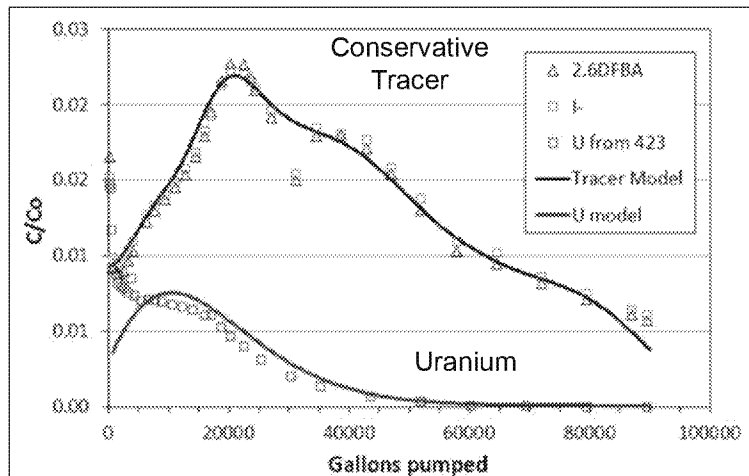
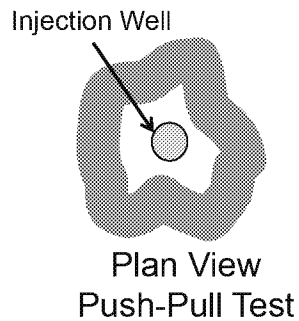
The geochemistry of an "evolved background groundwater" may be different from the current background groundwater due to rock-water interaction

Inset provided to point out groundwater locations

Point out that the predictive reactive transport modeling is very sensitive to small changes in geochemistry (especially pH); thus, the use of the final groundwaters will provide the best predictions

Field Pilot Tests

- Best field-scale data
- Inject and track unrestored or restored-zone water in an ore zone or downgradient zone that will be “overprinted” by future ISR



Main idea: To test the natural attenuation of uranium at the field scale in a much shorter time frame than natural flow rates
Currently being done at the Smith Ranch-Highland site where restored and unrestored ISR units are close to newly installed ISR units

Push-pull test is one example

A cross-hole test is being completed

Conclusions

- Batch tests, column tests, and predictive reactive transport modeling can be done before ISR begins as part of the decision making/permitting process by bracketing possible post-restoration conditions
 - Help address stakeholder concerns
- The best predictions require actual restored groundwater in contact with the downgradient solid phase
- Resulting modeling provides a range of natural attenuation rates and assists with designing the best locations and time frames for continued monitoring
- Field pilot tests are the best field-scale data and can provide the best model input and calibration data



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Mention that point one is a dilemma for stakeholders who want assurance of “no impacts” even before ISR work is conducted. Thus, the importance of having a modeled “range of reasonable possibilities” beforehand.